

DEEP SPACE DEEP OCEAN

Aramco Technology and
Operational Excellence Forum

Electric Power in Sea & Space:
Space Power Management and Distribution
Deep Dive 3: Session 2
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NASA's Needs and Requirements:

- High reliability / low maintenance
 - Long duration missions
 - Crewed missions
- Low mass
 - Low payload fraction
- Assembly and reconfiguration in space
 - Crew or automated
- Safety
 - Crewed missions



Needs and Requirements: environments

- Space environments are demanding
- Temperature extremes
 - ISS hardware without thermal controls would go from +250°F(full sun) to -250°F (full shade, facing away from Earth)
 - Lunar surface: (Equator: roughly -250°F to +250°F, polar -396°F)
- High radiation environments
 - Single event upsets: momentary shorts in silicon
 - Long term degradation

Needs and Requirements: environments

- Low pressure
 - Outgassing / cold welding of contacts
 - Plasma discharges
 - Corona discharges (neon sign pressures)
- High vibration during launch
 - >6 Grms typical for hardware

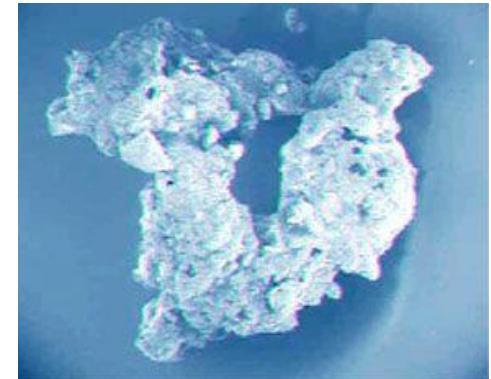
Needs and Requirements: environments

□ Poor heat transfer

- Microgravity means no natural convection even in a pressurized vessel
- In space heat must ultimately be radiated away.

□ Dusty / dirty

- Lunar regolith (dust) is like magnetic, conductive ground glass
- Martian dust



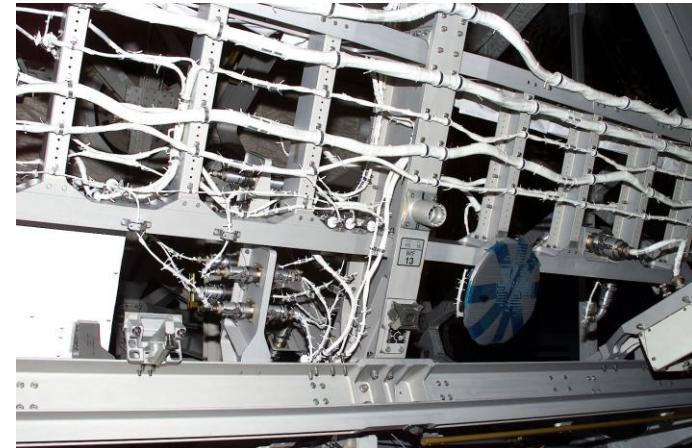
State of practice

□ Wiring

- Crimp connections
- Teflon™ and kapton™ insulation systems
- Silver and nickel plated copper conductors

□ Connectors

- Mil-spec derived
- “quick disconnect” designed for on-orbit use



State of practice

❑ Power control

- Large vacuum contactors for high power
- Solid state relay/circuit breaker for medium/small loads.

❑ Power topologies

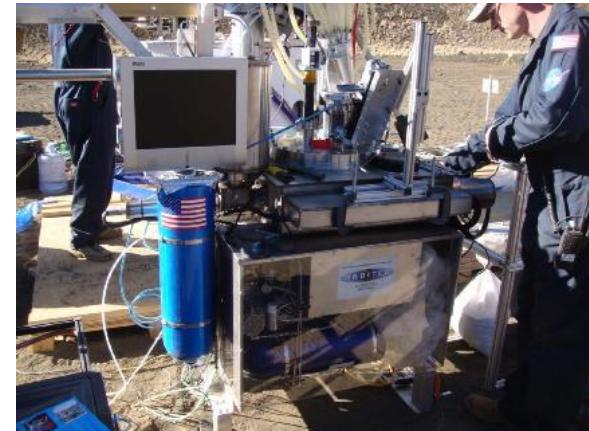
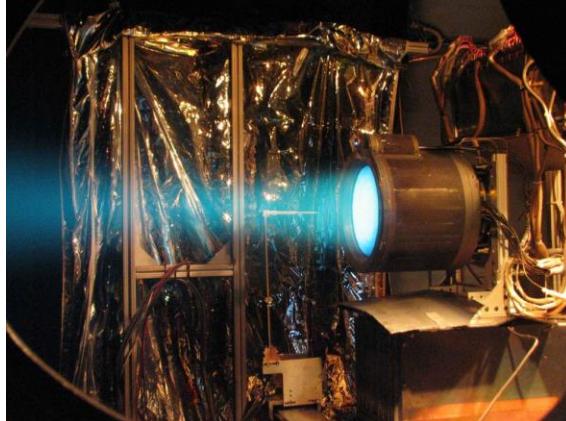
- Multiple busses with possible cross ties
- Batteries for stability
- Critical loads often take power from more than one bus.

State of practice

- ❑ Voltage levels: 28Vdc
 - Large base of equipment that uses 28V
- ❑ Voltage levels: 120Vdc, 160Vdc
 - ISS uses 160Vdc and 120Vdc
 - Orion uses 120Vdc
- ❑ Power transfer between systems (vehicle-to-vehicle)
 - DC/DC converter to control direction and magnitude of power transfer
- ❑ Lithium-Ion batteries
 - Large cell
 - Large arrays of small cells

Trends

- DC/DC converter efficiency
 - 97% with prototypes developed
 - Improved Variable Frequency Drives and other motor controls.
- Increase in DC bus voltages
 - 28V -> 120V -> 300V
- Higher power loads
 - Ion engines 100-1000 kW_e
 - Materials processing (In Situ Resource Utilization) 20-30 kW_e
- Partnering (Space Act Agreement)



Trends, continued

- ❑ Improved battery safety
 - Reducing fault propagation in large cell arrays.
- ❑ Autonomous reconfiguration in response to faults
- ❑ High temperature components and converters
 - Reduces mass of thermal radiator systems
- ❑ Improved radiation tolerance of power electronics
- ❑ Modular power electronics and control
 - Reduces need for redundancy
- ❑ Lighter wiring
 - Space qualified aluminum wiring systems
 - High strength carbon fiber for instrumentation
- ❑ Higher efficiency solar arrays
 - Moving technology from lab to space

Environmental comparison

